

Receiver Selectivity and How to Improve It

While there are a number of meaningful specifications of a radio receiver, perhaps the single most important to the hobbyist is that of **selectivity**: the ability of a receiver to admit or tune a desired signal to the exclusion of adjacent or undesired signals.

Generally we think of a receiver's selectivity as a qualitative factor in terms of poor, good, superior, etc., but this is not always proper. A lot depends on the frequencies you are tuning and their applications. Let's briefly consider two extremes.

For example, a voice channel in the crowded shortwave and HF amateur bands can get by with as little as 2.5 kHz of spectrum, but, in the television spectrum, decent video requires a minimum of 4 MHz. Therefore, you can't say that a television receiver with a "selectivity window" of 6 MHz has poor selectivity compared with a shortwave receiver with a 10 kHz window. On the contrary; it is the shortwave receiver in which up to four different signals may be present which has the poorer selectivity.

As you see, the measure and assessment of selectivity all depends on the bandwidth of the

desired signal. If you're copying Morse Code in a congested band, the desired selectivity might be as sharp as 250-500 Hz, tops. Single sideband voice reception does nicely at 2.1 kHz. Commercial programming on shortwave sounds best with a selectivity of about 6 kHz, but you need 4 kHz or even 2.5 kHz to dig out the weak ones at times of severe congestion.

AM mediumwave broadcasts on 550-1600 kHz need no more than 5 kHz selectivity, but any less means a loss of fidelity. Citizens Band receivers are at their best with selectivity of 5 kHz or less, although 10 kHz is more or less standard. The FM broadcast band of 88-108 MHz requires a selectivity of about 150 kHz in order to receive high fidelity signals inherent in this service. Receivers for weather satellite services need a selectivity of 20 kHz to as wide as 50 kHz for best performance.

Scanner receivers are a different story altogether. The VHF-UHF bands are more subject to controlled frequency assignments. This means that the selectivity specification is not nearly as critical as for the mediumwave and shortwave bands. In fact, VHF-UHF scanner receivers are notoriously a little less selective than their lower frequency counterparts because of two reasons:

(1) frequency assignments are made by the FCC with the idea of minimizing local area congestion and (2) allowed tolerances for variations in the frequency of the transmitted signal are greater for VHF-UHF. Receivers need to be less selective to be capable of clearly receiving all signals that are within the allowed tolerances. Even modern 0.001% tolerances can mean a frequency error of as much as 1540 Hz at 154 MHz.

Scanner receivers are designed with these variances in mind, with the result that most selectivity specs are about 15 kHz for those bands where the NFM mode predominates. VHF/UHF aero receiver selectivity may go as high as 25 kHz.

As an example: it is possible—even probable—that a receiver with a selectivity of 6 kHz will detect a powerful station that's 10 kHz or more away from the desired frequency. This is because there is no such thing as a perfect bandwidth "window." Therefore, this companion specification is stated in decibels (dB) or the degree to which undesired or off-frequency signals are rejected by the receiver.

This is the clue to most selectivity specifications. A typical selectivity specification for a scanner receiver might read something like this: -6 dB @ 9 kHz and -50 dB @ 15 kHz. Literally interpreted, this means that signals in the center of the designed selectivity "window" are referenced at 0-dB, and at 9 kHz away from that center, signals will be attenuated or reduced by 6-dB (a factor of 1/2) and at 15 kHz from the center of that window, signals will be attenuated by 50 dB (a factor of 3/1000).

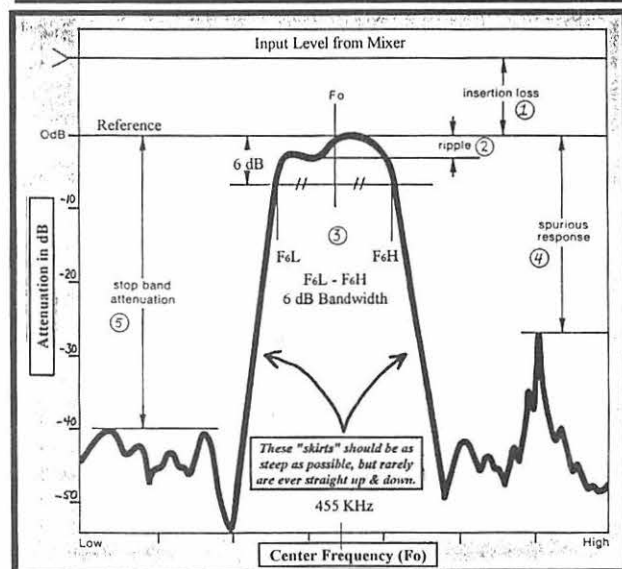
Selectivity specs for a typical shortwave receiver will read something like -6 dB @ 2.7 kHz and -50 dB @ 8 kHz, though this has to be taken loosely, because many shortwave receivers have two or three switchable selectivity settings—typically wide, medium and narrow. The above spec is representative of a narrow selectivity. See Figure 1 for a graphic depiction of how a filter works.

A receiver's selectivity is determined largely by the design of the filter that's located in the last Intermediate Frequency (IF) section. Single-signal selectivity is never established in the front end, or preamplifier section, where a wide range of signals have to be admitted. Likewise, the 1st IF contributes very little to the selectivity specification; neither does the 2nd IF of a triple conversion receiver. It is in the last or 3rd IF section where a special filter, usually ceramic but mechanical in some, is designed to pass the center frequency of that IF and a narrow band of frequencies on either side of center.

Ideally, this "pass band" will be flat on top with steep sides to make the graphed function appear like a square wave. Ideal is one thing; reality is another, with the consequence that the IF pass band will actually form a curve with a rippled top and a sloping pair of sides as shown in Figure 1. Most receivers employ ceramic filters because of good performance at lower cost. The best kind, however, is the mechanical filter, pioneered and still made by the Collins Division of the Rockwell Corp.

Mechanical IF filters are very expensive and rarely used now in any but the most expensive and professional equipment. The old R-390A military receiver uses several of these mechanical filters, which largely accounts for its excellent reputation through the years. The early Tram

FIGURE 1: CHARACTERISTICS OF AN IF FILTER



NOTES ON FIG-1

1. All IF filters have insertion loss, 2-3 dB typ, relative to the input level; the less, the better, usually.
2. All filters have "ripple"; not very important, but the less, the better.
3. The pass band of the filter is considered to be that spectrum between the -6 dB points. The filter is considered to reject frequencies above and below these points. The amount of rejection (dB) depends on the frequency. Outside the passband, the more rejection, the better.
4. All filters have "spurious response" or internally generated pseudo-signals that can interfere with reception of desired signals. The lower, the better. (-dB)
5. Stop Band of a filter is the opposite of pass band. It should be a consistent, highly attenuated level above and below the pass band, the lower, the better, though this level is rarely "flat".
6. SUMMARY: Pass Band (3) and Stop Band (5) are the most important specs of an IF filter. Spurious response (4) is also important, but less so.

Check Out the Curves

There is much more to selectivity specifications than the bandwidths we've discussed up to this moment. Bandwidth alone means little without a companion specification that defines the selectivity curve or pattern of the receiver.

Titan and Browning Golden Eagle CB receivers also employed Collins mechanical IF filters for superb rejection of "bleedover." HF receivers with sharp selectivity have always enjoyed immense success, and with good reason, since selectivity is more important than sensitivity below about 30 MHz.

What's Your Upgrade?

The rest of this article will establish ideas for improving the selectivity of your HF receiver. Referencing the previous discussion, you will not want to apply these techniques to television, video and FM broadcast receivers where the selectivity curve is specially designed and should be left as is. Selectivity improvements are desirable primarily for shortwave, CB and amateur HF receivers and, upon occasion, scanners.

Most receivers are designed with a 455 kHz last IF. More ancient and less common types that might be encountered are 262 kHz, 100 kHz, 7.8 MHz, 10.7 MHz and 11.275 MHz. While it's not impossible to improve the selectivity of receivers with oddball IF's, it is impractical to do so because of the difficulty in acquiring the necessary upgrade filters. Our efforts here will focus on sprucing up only those with 455 kHz IF sections.

In general, the best way to improve the selectivity of a receiver is to replace the stock, average performance IF filter with an upgraded model. A variation of this technique involves the addition of a second similar or better IF filter in series with the first, leaving it in place. Another approach is to identify those transistors which make up the 455 kHz IF section and replace all emitter bypass capacitors with 455 kHz bypass resonators.

A sometimes possible method to dramatically improve selectivity is to add a crystal lattice filter to the IF section immediately before the 455 kHz section. This will be the 2nd IF in a triple conversion receiver or the 1st IF in a dual conversion receiver. This technique is easier said than done because of the expense of crystal lattice filters in the first place (\$60-\$100), not to mention a general unavailability of such filters for just any Brand-X 1st or 2nd IF. Last IF's of 455 kHz are rather standard, but there are no apparent standards for 1st and 2nd IF's.

Still, I have had immense success with this latter method applied to the Cobra 2000-GTL and Cobra 148-GTL CB radios, which use a 7.8000 MHz 1st IF and a 455- kHz 2nd IF. There is a small 7.8 MHz 2-pole crystal filter in the first IF of these fine CB rigs for the purpose of filtering mixer and oscillator noise. This filter literally cries out for removal and replacement with a 6 or 8-pole crystal lattice 7.8 MHz SSB filter. These filters cost upwards of \$100, but are free, or nearly so, if cannibalized from another rig. 7.8

Sources

IF Filters & Resonators:

Murata-Erie North America, LTD.	NTK Technical Ceramics
2200 Lake Park Drive	1200 Business Ctr. #300
Smyrna, GA 30080	Mt. Prospect, IL 60056
404-436-1300; Fax 404-436-3030	708-824-1133

The Famous Collins Mechanical IF Filter

Collins, Div of Rockwell Int'l
2990 Airway Ave.
Costa Mesa, CA
714-641-5311

IF Filter Upgrades, Improvements, Kits

Kiwa Electronics	Sherwood Eng. Inc.
612 South 14th Ave.	1268 S. Ogden St.
Yakima, WA 98902	Denver, CO 80210
509-453-KIWA	303-722-2257 Fax: 303-744-8876

Dalong Electronics, LTD.

Clayton Wood Close
West Park, Leeds
England LS16 6QE

MHz is a common transmitter and receiver IF frequency in some older SSB-CB rigs, and I've salvaged many of those large, silvery, crystal lattice filters from decrepit rigs like the Midland 13-893, 13-895, Cobra 138, etc.

If you are lucky enough to find and resurrect one of these old fossils from the bone yard, then locate and remove FT-2 in your Cobra 2000 GTL or Cobra 148-GTL and replace it with one of these larger, more effective filters for greatly enhanced selectivity in the AM-mode. FT-2 looks like an HC-49/u or HC-18/u crystal except that it has three leads: IN, OUT and ground. The much larger crystal lattice filters also have the same three leads, so replace FT-2, pin for pin.

If "bleedover," "splatter," or "wash," as it may be called in different parts of the world, is a problem in your Cobra 2000-GTL or 148-GTL, then this selectivity upgrade will make adjacent channel interference a thing of the past! Crystal lattice filters typically reject undesired signals by 60-dB or more and have a bandwidth of less than 5 kHz.

The rest of you stay tuned until next month when we'll get down to some gory detail for beefing up the selectivity of more receivers. Don't sigh or get impatient now, because you need more information anyway, and this coming month will give you time to acquire it. If you're an expert, there is already enough information in this article to get you moving. If you're a novice, then the wait and accumulation of information will be well worth your time.

See the sidebar for resource data relative to IF filters and contact those companies for their product catalogs and literature. Tell them that *Monitoring Times* and I referred you. Do it right away so you can be ready to go next month. Until then...73.

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How to Improve Receiver Selectivity — II

Last month, we dissected the subject of receiver selectivity. This month, we'll dispense with the head-tripping theory and just run amok through the receiver's innards in our quest for profoundly sharp selectivity.

Solution 1:

It is probable that most receivers can be improved by the hobbyist to yield sharper selectivity. In general, there are three approaches to this goal. This first approach is usually the easiest, but it requires some unusual parts: emitter bypass resonators.

The section of the receiver in which this approach should be focused is the last IF section, usually 455 kHz. This section of the receiver contains anywhere from two to a half dozen or more transistors which amplify the 455 kHz IF signal before it is sent to the Detector circuit. Resident within this section will be the predominant selectivity determining devices, the IF filter and possibly one or more tuned transformer "cans" (DON'T adjust them!) between each IF amplifier transistor. Refer to Figure 1 for a simplified diagram of a typical receiver's last IF section.

Now identify the amplifier transistor(s) for that section. On the emitter of each IF amplifier transistor will be one or two resistors to ground, and a capacitor at each resistor to ground. Let me submit that several dB of selectivity can be added by replacing those emitter bypass capacitors with "emitter bypass resonators." The short theory of this approach is that capacitors are non-selective at IF frequencies and allow the amplifiers to boost all signals by an equal amount. Emitter bypass resonators, on the other hand, allow full amplification ONLY of signals which are at the designed center frequency range (455 kHz). Off-center or adjacent signals are amplified less when emitter bypass resonators are used in place of capacitors.

To replace all emitter bypass capacitors in the last IF section, first be sure to identify and locate these components in your receiver. If you can access the bottom side of the circuit board where the capacitors are soldered, so much the better. Desolder and remove them. If the solder side of the circuit board is not readily accessible, it may be possible to carefully crush each capacitor in the middle of its body so as to preserve the leads. Then gently crush the residual capacitor material that clings to each lead until the stuff crumbles off, leaving exposed wires. Either way, solder an emitter bypass resonator to the points where each emitter bypass capacitor was removed.

This method of beefing up receiver selectivity is not highly technical and requires little more than the ability to identify and locate capacitors in

a specific circuit. A soldering pencil and a diagonal cutting pliers are among the most complicated tools that you'll need. It is advisable to have the service manual for your receiver before attempting this and any other serious modifications to avoid removing the wrong components.

Emitter bypass capacitors are usually (but not always) of the ceramic disk variety; two-leaded, thin disk shaped gizmos about 3/16" to 5/16" in diameter. The value is not critical and may range from 0.001 F to as high as 1.0 F; 0.1 F is common. See the sidebar in last month's article for sources of emitter bypass resonators, IF filters and other materials for selectivity enhancements. The Murata-Erie BF-455A is known to be an effective emitter bypass resonator.

Solution 2:

Probably the most dramatic improvement you can make to your receiver's selectivity is to add another filter in series with the stock filter. Depending on the receiver, there may already be switchable IF filters to offer selectivity settings of wide, medium and/or narrow. In this case, it makes little sense to improve the selectivity of the wide and/or medium filters, since selectivity is not always important when reception conditions are not adverse. It's when the receiver is already set to NARROW and you still can't dig out those weaker stations adjacent to the power blasters that you need the utmost in selectivity.

Therefore, if your receiver has two or more selectivity settings (not SSB and CW) then it's the narrowest section that you'll want to modify in this approach. If your receiver doesn't have selectable bandwidths, then you have no choice but to modify the one filter section.

Probably the easiest and still a very effective method is to install a 2nd IF filter in series with the existing one. The 2nd one need not be anything special and, in fact, can be salvaged from junked CB or ham rigs with little difficulty and virtually no cost. Most surplus and salvage IF filters are small, solid plastic, boxy devices about 5/16" L x 1/4" W x 5/16" H, with three to five wire leads on the bottom. See Figure 3 for pin diagrams of common IF filters. These low-cost IF filters are usually colored black, although I have seen white and blue, too.

The buzzword for this type of device is "ceramic IF filter," in case you need to ask around. Virtually every CB radio since the middle 1960's comes with one, and there must be a million junkies laying around from which you can salvage a ceramic IF filter. The part number that's stamped on the majority of these filters will be something like "CFU-455" with a letter suffix of I or H and sometimes, HT. Most are made by Murata.

One caution here is that none of these CFU-455(x) filters will be good enough to serve as a stand-alone replacement filter for the stock one. Use this type of filter only as a supplement to the stock IF filter. Here is how to install it:

Locate the stock IF filter. At both its INPUT and OUTPUT ports will be found a "coupling capacitor" of about 0.01 F. Remove one of those capacitors or carefully crush it to preserve its wire leads, and presto, there are your IN & OUT points at which to connect the new filter! It's generally best to install your new filter on the INPUT side of the stock filter, but if the OUT side is more convenient, feel free. The best approach here is to solder a short, fairly stiff wire to each of the two holes or leads where the coupling capacitor was removed. Solder the IN & OUT terminals of your new filter to these short stiff wires. Then solder a short wire from the filter's ground terminal to a nearby receiver ground spot.

This basically completes the job, except that you should install a new coupling capacitor between the new filter and the outermost of its two leads, IN or OUT. Where, depends on whether you installed your new filter on the IN side of the stock filter or the OUT side. The bottom line is that the new coupling capacitor (0.01 F will do) must go between the new filter and the receiver circuit. It is OK for the two filters to directly connect to each other (see Figure 2), but each filter needs to be isolated from the receiver circuitry by a coupling capacitor. The side of the stock filter that you did not modify will already have such a capacitor so you need only add one to the side you worked on.

An ideal place for the new capacitor will be between one of the leads of the new filter and the stiff wire leads that you installed at first. Figure 2 shows exactly what to do. Also note there will be a resistor on both sides of the stock IF filter. Make sure these resistors remain active in the circuit, or add a new one of the same value to the outer side of the new filter if need be.

This second approach is not perfect, because an additional IF filter will slightly reduce the IF-gain by an amount equal to the "insertion loss" of the new filter, typically 2-3 dB. This is generally of no significance and need not be cause for concern. The slight loss of gain is amply compensated by a higher signal-to-noise ratio and better selectivity. Still, it is a minor compromise.

Solution 3:

Possibly the best approach to enhancing your receiver's selectivity is to replace your receiver's so-so IF filter with a good one! Pop out the old filter and install a new one, lead for lead, never minding any excess ground leads that may have been on the old one. Even if the new filter's leads

don't match the old one, it is a simple matter to install 1/2"-3/4" stiff wires into the existing holes and then position them to mate with the terminals of the new filter. Lead length is not super critical at 455 kHz, but you do want to keep lengths as short as possible. See Figure 3 for the pinouts that will be encountered in most IF filters.

The trick here is to acquire a filter that's better than the one to be removed. The sources given in last month's article will be able to assist you in this selection. For those of you who aren't too keen on doing the necessary research, I heartily recommend Kiwa Electronics for their line of replacement high performance IF filters for many receivers. Give them a call at (800) 398-1146 or (509) 453-KIWA if you're not sure what's best for your rig. See Kiwa's ad in this issue, and last month's sidebar, for other IF filter resources available to you. You need no longer be stifled and frustrated with mediocre selectivity, even in bargain receivers!

Experimenter's Support Line

By the way, I am pleased to be able to provide technical support on this and many other electronic projects via The Hertzian Intercept BBS at (619) 578-9247 after 6pm and before 1pm, PDT, weekdays and 24 hrs on weekends. I am also available for chatting and discussing radio technology with you via the FidoNet SCANRADIO and SHORTWAVE conferences. Log on to any Fido affiliated BBS in the world that carries either of these two conferences to be in direct contact with me and thousands of other inspired radio hobbyists worldwide. If your favorite (local) FidoNet BBS does not presently carry these conferences, request your SysOp to bring them in. FidoNet is an amateur computer network of some 20,000 bulletin boards from Australia to Zambia and all points between.

If you've been reluctant to communicate with me by mail, (and with good reason; I can only correspond with just so many in a day's time), I recommend you connect to this network. I will be happy to mail you a list of Fido BBS's in your local calling area for an SASE or you can request a BBS list for your area via The Hertzian Intercept BBS, per above.

Computer networking with fellow hobbyists adds a new dimension to the excitement of otherwise passive radio monitoring. It's similar to being a ham or a CB'er where you get to TALK to others in addition to listening to them. The combination of Computers and Radio is not going to be licked, so it may as well be joined. After all, communications is what we're all about, eh?

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FIGURE 1: MODIFYING A RECEIVER'S LAST I.F.

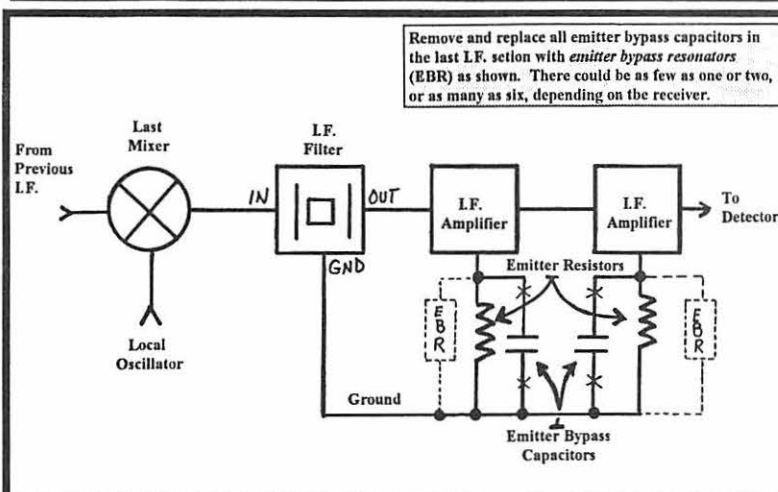


FIGURE 2: INSTALLING A SERIES I.F. FILTER

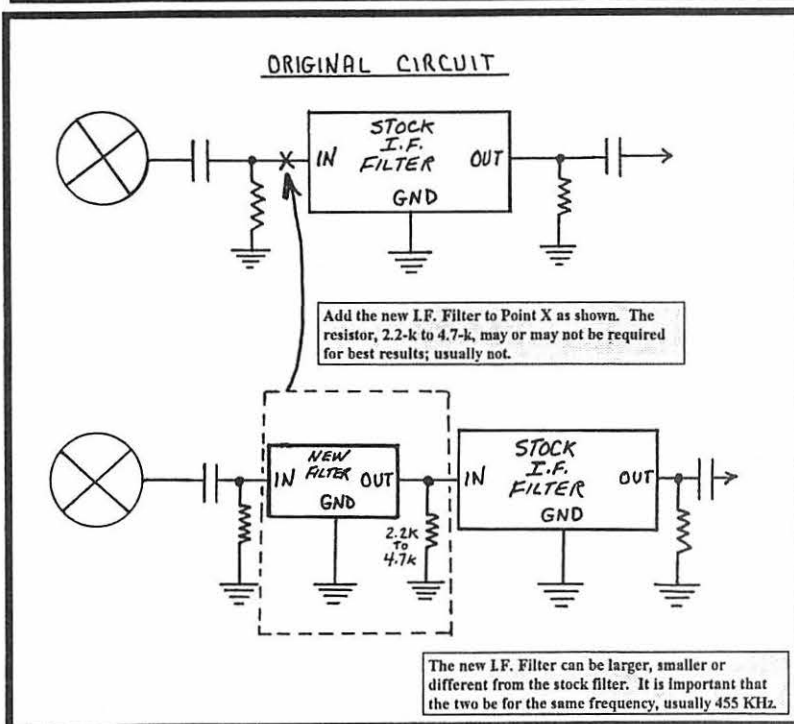


FIGURE 3: PINOUTS OF VARIOUS I.F. FILTERS

